Temporal Characteristics of the Subjective Contour Formation: A Preliminary Report

著者	TAKIURA Takayuki
journal or publication title	Tohoku psychologica folia
volume	64
page range	1-6
year	2006-03-31
URL	http://hdl.handle.net/10097/54712

Tohoku Psychologica Folia
2005, **64**, 1−6

Temporal Characteristics of the Subjective Contour[1] Formation: A Preliminary Report

TAKIURA TAKAYUKI (滝浦孝之)[2]

(Hiroshima Shudo University)

The subjective contour of Kanizsa type has three phenomenal characteristics, that is, subjective boundary, brightness difference and apparent depth. Many authors have argued on the causal relationship among these characteristics for the subjective contour formation. In the present study, clarity of the three phenomenal characteristics of Kanizsa square was separately rated to know their order of formation. The result suggested that the subjective boundary developed faster than the other two, whose difference in order was not detected.

Key words: subjective contour, subjective boundary, apparent brightness, apparent depth

Introduction

The subjective contour of Kanizsa type is accompanied by the three phenomenal characteristics, that is, subjective boundary, brightness difference and apparent depth (Kanizsa, 1979). These phenomenal characteristics are supposed to be caused by the separate processes (Watanabe & Oyama, 1988).

Using the causal inference method, Watanabe and Oyama (1988) investigated the causality between subjective boundary and its concomitant perceptual characteristics. Their results showed that for subjective contour the clarity of subjective boundary influenced the brightness difference and apparent depth, suggesting that the former was the cause of the latter. Takahashi (1999) presented the model of subjective contour perception in which the phenomenal characteristics of subjective contour are generated in the order of surface with subjective boundary, brightness difference and apparent depth. In this model, the surface of the subjective contour was supposed to be formed by the perceptual segmentation of the visual field made with the alignment cue in the inducing figure (Rock & Anson, 1979), and the change of apparent brightness was explained as the result of the figure-ground contrast effect given by the change of the apparent depth of the subjective surface, which is caused by the perceptual stratification in the visual field made with the incompletion cue in the elements of the inducing figure (Rock & Anson, 1979).

In order to see the temporal characteristics of the perception of Kanizsa-type subjective

1. Some authors have used the term subjective contour or illusory contour to indicate only the subjective boundary given rise to by the inducing figure, and others used it to indicate the illusory figure surrounded by the subjective boundary. In the present paper, the term of subjective contour refers to the figure delineated by the subjective boundary, which belongs to the figure.
2. Department of Human Sciences, Faculty of Humanities and Human Sciences, Hiroshima Shudo University, 1-1-1, Ozuka-higashi, Asaminami-ku, Hiroshima, 731-3195, JAPAN. [e-mail: takiura@shudo-u.ac.jp]

contour, several authors investigated the change in the clarity of subjective contour as a function of the exposure time of the inducing figure (Parks, 1994; Spehar & Clifford, 2003; Takahashi, 1991, 1993, 1994), which is called the analysis of the microgenetic process of subjective contour perception. In these studies it was found that the clarity of subjective contour increased with the increase of the duration of the inducing figure to several dozens or hundreds of millisecond beyond which it became independent of the inducing figure duration. These studies, however, measured only the clarity of the whole percept of subjective contour and did not rate the clarity of individual phenomenal characteristic, respectively. In the present experiment, the three phenomenal characteristics, subjective boundary, brightness difference and apparent depth, of Kanizsa square were separately measured in their clarity to know their order of formation.

Method

Observers

Fifteen undergraduate volunteers ranging in age from 18 to 23 years participated in the experiment. They were naive as to both the form perception task and the tachistoscopic observation and did not know the purpose of the present experiment. All had normal or corrected-to-normal visual acuity.

Apparatus and stimuli

The stimuli were generated on a personal computer with a Pentium (NEC PC-9821Xa10) and were presented on a 14 inch CRT monitor with a resolution of 640 × 400 pixels and a refresh rate of 56.4 Hz (SANYO CMT-A14U2S). The stimuli were viewed binocularly at a distance of 1 m. The experiment was run under DOS with interrupts disabled in order for the timing of the stimulus to be controlled by the accurate count of refresh cycles of the video signal.

The inducing figure consisted of four notched black disks of radius 1°. These elements were placed in order for the area surrounded by them to form an imaginary square of side 3.3°. This inducing figure produced the clear perception of Kanizsa square for all the observers of the present experiment if it was presented constantly. The experiment was carried out in the illuminated room, and the luminance of the background and the inducing figure was 17.8 cd/m^2 and 1.4 cd/m^2, respectively.

Durations of the inducing figure expressed in terms of frame number were 1, 3, 6, 9, 15, 30, 45 and 60 frames. The stimulus duration is a different variable than the time from the stimulus onset, because the former is the time passing from the onset to the offset of the stimulus and the latter is the time that is independent of the timing of the stimulus offset. The time course of the visual response is usually investigated with the time after the onset of the stimulus, not with the stimulus duration, as the independent variable. In the analysis of the microgenetic process of subjective contour perception, however, processing both the inducing figure and the subjective contour is supposed to be terminated at the end of the stimulation of the inducing figure by the interruptive effect of the backward mask presented at the offset of the inducing figure. Wasserman and Kong (1974) criticized the view that the stimulus duration can be used as the independent variable in the study of the development of the visual response with time, but the present report followed the previous studies on the microgenetic process of subject contour perception in the point of the independent variable.

No backward mask was presented at the offset of the inducing figure, since it seemed that the kind of the backward mask (rings, outlined pacmen and random dots) or the presentation of the mask itself do not make the essential change in the microgenetic process for the formation of subjective contour (Takiura, 2005).

At the start of each trial, a beep tone was briefly presented as a warning tone. Just after the offset of the tone, four black lines of 0.04° wide by 1.85° long in each size were presented above, below, at the right and the left to the inducing figure for Two seconds. Observers were asked to keep themselves from blinking during the time from the warning tone to the offset of the inducing figure, and to fix their gaze upon the imaginary crossing of four lines. Two seconds after the offset of these fixation lines the inducing figure was presented. Inter-trial interval was about 1 s.

Procedures

The session was divided into three blocks. In each block, rating of the clarity was made for one of three phenomenal characteristics of subjective contour, that is, subjective boundary, brightness difference and apparent depth. In each block, the inducing figure was presented continuously as the modulus before the measurements. Clarity of each phenomenal characteristic of subjective contour for the modulus was called 10. Observers were asked to report the clarity of one phenomenal characteristic by assigning a number to each percept of subjective contour in proportion to its magnitude relative to that for modulus. The inducing figure durations were tested in random order. In each block, rating was repeated three times for each duration. The order of the blocks was determined at random. The session was repeated three times for each observer. So a total of nine ratings were made for each combination of phenomenal characteristic and inducing figure duration per observer.

Practice trials were given for each observer before the measurement.

Results

The mean rating for each condition for each observer was used in the data analysis.

In Figure 1, the changes of the mean clarity of subjective boundary (circles), brightness difference (upright triangles) and apparent depth (inverted triangles) are shown as a function of inducing figure duration in terms of frame number with 15 observers. The two-way ANOVA (phenomenal characteristic × inducing figure duration) showed that there were significant main effects of both the phenomenal characteristic, $F(2,28) = 7.47$, $p < .01$, and the inducing figure duration, $F(7,98) = 16.83$, $p < .01$. The interaction between the phenomenal characteristic and the inducing figure duration was not significant, $F(14,196) = 1.52$, $p > .1$. Multiple comparisons using Fisher's LSD test for the main effect of the phenomenal characteristic revealed that there was no significant difference in the rated clarity between the brightness difference and apparent depth, and the clarity was significantly higher for subjective boundary than for the other two phenomenal characteristics ($p < .05$). Clarity of each phenomenal characteristic of Kanizsa square was increased with the increase of the duration of the inducing figure below 30-45 frames.

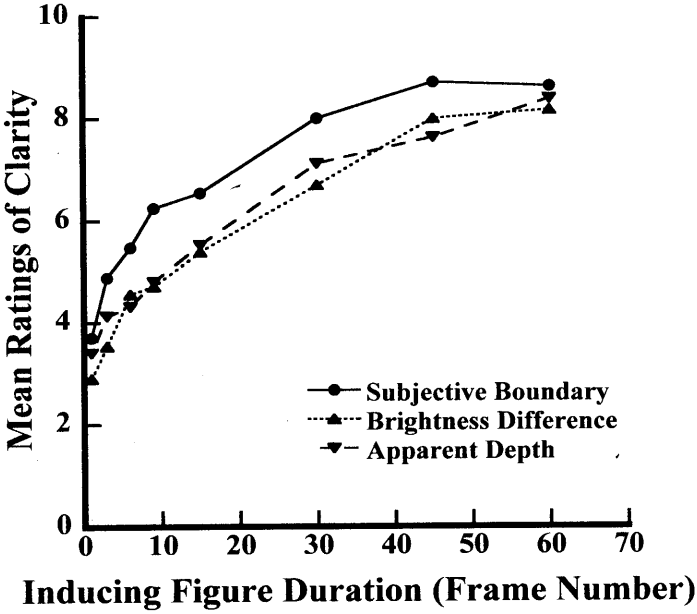

Figure 1. Mean rated clarity of subjective boundary (circles), brightness difference (upright triangles) and apparent depth (inverted triangles) of Kanizsa square as a function of the duration of the inducing figure in terms of frame number for 15 observers.

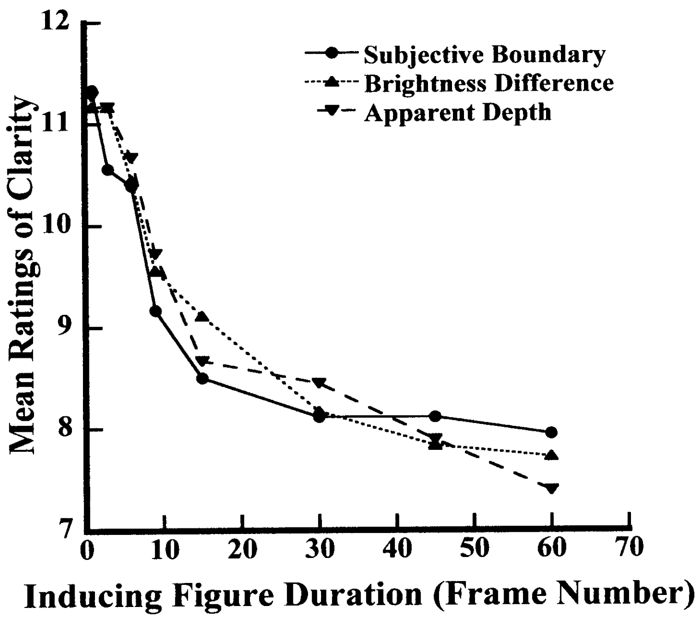

Figure 2. The mean data from the two observers who gave results quite different from the other 13 observers.

Data from the 2 observers are shown in Figure 2, which were quite different from those from the other 13 observers. For these two observers, the clarity of subjective contour decreased with the increase of the inducing figure duration below 15-30 frames. They reported that they perceived the contrast between the black inducing figure and a white square being higher when the durations of the inducing figure were shorter. Excluding the data from these two observers, however, did not essentially change the results of the analysis.

Discussion

With the technique of the microgenetic process analysis of the Kanizsa-type subjective contour, the present experiment showed that the subjective boundary formation preceded the growth of the brightness difference and the apparent depth. This result cannot be explained from the view that the increase of the surface brightness causes the subjective boundary (Brigner & Gallagher, 1974; Jory & Day, 1979; Kennedy & Lee, 1976) or the development of the apparent depth comes before the formation of the subjective boundary (Coren, 1972). But it is in agreement with the prediction by the three-factor model presented by Takahashi (1999) and with the conclusion of the experimental study of Watanabe and Oyama (1988) with the causal inference method that in the subjective contour the formation of subjective boundary was the cause of the brightness difference and apparent depth. The present result also suggests that the change of the brightness and depth of the surface of subjective contour does not occur only after the completion of the formation of subjective boundary but follows it in a cascade-like manner. That is, the partial formation of subjective boundary seems to trigger the perception of brightness difference and apparent depth.

The order of formation between the brightness difference and the apparent depth was not discriminated. This may suggest that these two phenomenal characteristics of Kanizsa square develop in parallel. The possibility, however, remains that the difference in the rate of temporal development between these two phenomenal characteristics was too small to be detected in the present experiment condition.

In the present experiment, the clarity of the phenomenal characteristic of subjective contour was separately rated. One may doubt whether the observers could isolate one phenomenal characteristic from each other to assess its magnitude. We believe that the separate measurement of the clarity of each phenomenal characteristic by the method of magnitude estimation. In some kinds of psychophysical experiment, the magnitude of the single attribute of the stimulus as the brightness, color or duration can be rated and the results were reported which are similar to those from the experiments with the other psychophysical methods based on the stimulus discrimination, which belong to the different category of psychophysical observation than the magnitude estimation technique (Boynton & Onley, 1962). For example, in the studies on the Broca-Sulzer phenomenon, which refers to the fact that a shorter flash can look brighter than a longer flash, the brightness can be separated from the other sensory dimensions as the perceived duration or color and can be rated by the magnitude estimation technique, producing results comparable to those from the studies with the brightness matching task (Aiba & Stevens, 1964;

Corwin, 1978; Osaka, 1977). Takiura (1998) directly confirmed this by comparing the brightness matching data and the magnitude estimation data obtained under the same stimulus condition.

We must, however, also admit that it remains questionable whether the independent rating of each characteristic of the stimulus by the same observer is ensured under all the stimulus conditions[3]. The perfect separability of one sensory dimension from the others for the identical observer has not been confirmed enough both theoretically and experimentally. In the present experiment, it is possible that no significant difference in the rating was detected between the brightness difference and the apparent depth because of the observers' confusion between these two phenomenal characteristics. So, in the following paper, we will report the results with the solution of this problem.

References

Aiba, T. S., & Stevens, S. S. (1964). Relation of brightness to duration and luminance under light- and dark-adaptation. *Vision Research*, **4**, 391-401.

Boynton, R. M., & Onley, J. W. (1962). A critique of the special status assigned by Brindley to "psychophysical linking hypothesis" of "Class A." *Vision Research*, **2**, 383-390.

Brigner, W. L., & Gallagher, M. B. (1974). Subjective contour: apparent depth or simultaneous brightness contrast? *Perceptual and Motor Skills*, **38**, 1047-1053.

Coren, S. (1972). Subjective contour and apparent depth. *Psychological Review*, **79**, 359-367.

Corwin, T. R. (1978). The effect of retinal eccentricity on the Broca-Sulzer phenomenon. *Vision Research*, **18**, 865-867.

Jory, M. K., & Day, R. H. (1979). The relationship between brightness contrast and illusory contours. *Perception*, **8**, 3-9.

Kanizsa, G. (1979). *Organization in vision: essays on Gestalt perception*. New York: Praeger.

Kennedy, J. M., & Lee, H. (1976). A figure-density hypothesis and illusory contour brightness. *Perception*, **5**, 387-392.

Osaka, N. (1977). Perceived brightness as a function of flash duration in the peripheral visual field. *Perception & Psychophysics*, **22**, 63-69.

Parks, T. E. (1994). On the microgenesis of illusory figures: a failure to replicate. *Perception*, **23**, 857-862.

Rock, I., & Anson, R. (1979). Illusory contours as the solution to a problem. *Perception*, **8**, 665-681.

Spehar, B., & Clifford, C. W. G. (2003). When does illusory contour formation depend on contrast polarity? *Vision Research*, **43**, 1915-1919.

Takahashi, S. (1991). Operation of figural cues in the microgenetic process of subjective contour perception. *Japanese Journal of Psychology*, **62**, 212-215. (In Japanese with English abstract.)

Takahashi, S. (1993). Microgenetic process of perception of subjective contour using "self-sufficient"-inducing pattern. *Perceptual and Motor Skills*, **77**, 179-185.

Takahashi, S. (1994). Microgenetic process of subjective contour perception in "noise-containing" inducing patterns. *Japanese Psychological Research*, **36**, 195-200.

Takahashi, S. (1999). Mechanism of subjective contour perception. *Journal of the Faculty of Letters Nagoya University, Philosophy*, **45**, 139-149. (In Japanese.)

Takiura, T. (1998). A relationship between the brightness enhancement in extrafovea and the on-responses estimated by the visual masking technique. *Tohoku Psychologica Folia*, **57**, 58-74.

Takiura, T. (2005). Effects of the backward mask on the microgenetic process of Kanizsa square perception. *Studies in the Humanities and Sciences*, **46-1**, 1-16. (In Japanese with English abstract.)

Watanabe, T., & Oyama, T. (1988). Are illusory contours a cause or a consequence of apparent differences in brightness and depth in the Kanizsa square? *Perception*, **17**, 513-521.

---

3. The author is grateful to Dr. Jiro Gyoba for his comments on this point.

(Received October 2, 2005)
(Accepted December 12, 2005)